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AUTHOR Barry, Dana M.
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ABSTRACT

Burning things like wood, fossil fuels, and gasoline are the easy way of capturing energy in today's society. In this paper, the risks of using combustion as an energy source are discussed and acid rain, air pollution, and greenhouse effects are described. Additional student activities and resources are included. In addition to being informative, it encourages students in grades 7-12 to analyze these risks and to brainstorm for solutions such as alternate energy sources and forms on energy conservation. (YDS)

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THE ENVIRONMENTAL RISKS OF USING COMBUSTION AS A SOURCE OF ENERGY

By

Dana M. Barry, Ph.D., C.P.C.

Editor and Technical Writer - Clarkson University, USA
Professor and Honorary Advisory Council Member - Ansted University, Malaysia

(CONFCHEM - 2001)

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Introduction

Our society burns things to obtain energy. Wood, coal, oil and kerosene are burned to heat homes and buildings. Gasoline and diesel fuel are burned to run cars and trucks, while jet fuels are used in planes. Wood and fossil fuels (those formed from partially decayed plant and animal matter of living organisms from the past) are cheap and abundant and the devices used to burn and capture their energy are easy to build and use. Therefore most of the world's energy comes from the burning of these organic compounds, chemicals containing carbon. The resulting combustion products pollute the Earth's atmosphere and threaten to change our global climate through the greenhouse effect.

This paper presents the risks of using combustion as a source of energy. It describes the greenhouse effect, air pollution, smog, and acid rain. In addition to being informative, it

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encourages people in general as well as students in grades 7 -12 to analyze these risks and to brainstorm for solutions such as alternate energy sources and energy conservation. Student activities and resources for further reading are also provided.

Greenhouse Effect

Efficient combustion mainly produces water and carbon dioxide. Water is necessary for life and carbon dioxide is released from the life processes of animals and used in the life processes of plants. These products seem to be harmless. However large amounts of carbon dioxide, emitted as a result of increased energy demands, threaten to change the world's climate through the greenhouse effect. This effect is like that of growing temperature-sensitive plants in a greenhouse. The glass walls and roof of a greenhouse allow the sun's radiation to penetrate. Once inside, the radiation is converted to heat and absorbed. The heat, trapped within the greenhouse, allows plants to grow and thrive.

The Earth's atmosphere acts like a greenhouse. Carbon dioxide and other gases of the atmosphere trap solar heat. This is very important for life as we know it today. The presence, of just the right amount of carbon dioxide and other greenhouse gases, is needed to maintain the proper temperature range to support life. (Other greenhouse gases include methane, oxides of nitrogen, ozone and chloro-fluorocarbons). The Earth's atmosphere contains about 0.03% carbon dioxide with a density between the two extremes of its planetary neighbors Venus and Mars. Venus is very hot because it has a dense atmosphere rich in carbon dioxide, while Mars is very cold because it has very little atmosphere with very little carbon dioxide.

Our concern is that the amount of carbon dioxide in the Earth's atmosphere is increasing and it is increasing more rapidly than it has in the past. This increase in the amount of carbon

dioxide can produce dramatic changes in climate. For example, doubling the amount of carbon dioxide in the atmosphere can increase the average global temperature by about 1.5 - 4.5 degrees C through the greenhouse effect (1). New studies suggest that average worldwide temperatures could rise by up to 10 degrees over the next century (2). This is much higher than the 2.5 to 5.5 degrees previously thought. A team from Imperial College in London recently released results from a study which compares the atmosphere of 30 years ago to the present one. The results provide direct experimental evidence for a significant increase in the Earth's greenhouse effect. This evidence is based on a comparison of satellite measurements taken in 1970 and in 1997 (3).

Carbon dioxide concentrations tend to be greatest at the poles. (This may be due to the absence of plants). Therefore the ice caps could melt causing the seas to rise. In addition to flooding problems, changes in rainfall distribution could cause droughts and great harm to agriculture and water sources.

Student Activity

1. Take the class to visit a greenhouse. Have the students record their observations and reactions. Discuss their information in class.

2. Have the students brainstorm about environmental risks that can result from the greenhouse effect. Also have them brainstorm to come up with possible solutions. (**Hint:** Employ energy conservation to decrease our overall demand for energy).

Air Pollution / Smog

Air pollution is the presence of substances (not normally there) that are harmful to man,

animals, or plant life. It includes sulfur dioxide and nitrogen oxides.

Fossil fuels such as petroleum consist of hydrocarbons (made up of hydrogen and carbon) and some impurities of sulfur compounds and sometimes traces of compounds of metals such as nickel and vanadium. Most of the sulfur of coal is combined with iron in pyrite minerals. When coal and petroleum are burned, their hydrocarbons and impurities are oxidized. The sulfur of pyrite that remains in coal oxidizes to sulfur dioxide as shown.

(1) $4\ FeS_2 + 11\ O_2 \longrightarrow 2\ Fe_2O_3 + 8\ SO_2$

pyrite oxygen iron oxide sulfur dioxide

Sulfur dioxide is an irritating gas which enters the air as a pollutant. Once in the atmosphere and remaining in contact with oxygen of the air, sulfur dioxide can further oxidize to sulfur trioxide.

(2) $2\ SO_2 + O_2 \longrightarrow 2\ SO_3$

sulfur dioxide oxygen sulfur trioxide

Sulfur trioxide is a highly irritating gas that can produce choking sensations at very low concentrations - approximately one part per million (4).

Nitrogen oxides form another group of air pollutants. The nitrogen of these pollutants primarily comes from the air rather than from impurities in fuels. At very high temperatures, molecules of the air's nitrogen and oxygen combine to form nitric oxide.

(3) N_2 + O_2 ----------> 2 N O

nitrogen oxygen nitric oxide

Nitric oxide can then react with additional oxygen to form nitrogen dioxide.

(4) 2 N O + O_2 ----------> 2 NO_2

nitric oxide oxygen nitrogen dioxide

Nitrogen dioxide is a red- brown gas that is toxic and causes irritation to the respiratory system and eyes. Ultraviolet radiation of the sun can remove one of the oxygen atoms from the nitrogen dioxide.

(5) NO_2 ----------> N O + O

nitrogen dioxide sunlight nitric oxide oxygen atom

This oxygen atom can react with a diatomic oxygen molecule to produce ozone, an irritating toxic gas which is a lung irritant in the lower atmosphere. However, ozone in the stratosphere is very useful because it protects us from the sun's damaging ultraviolet radiation.

The oxygen atom can also react with unburned hydrocarbons (auto exhaust) to make new pollutants.

(6) O + O_2 ----------> O_3

oxygen atom oxygen molecule ozone

To make things worse, these new pollutants can further react with oxygen molecules and nitrogen oxides to produce more pollutants. This complex combination of all the products from the initial interaction of sunlight and nitrogen dioxide is called photochemical smog. It appears as a brown haze in our cities. Keep in mind that smog is a persistent combination of smoke and fog occurring under appropriate meteorological conditions in large metropolitan or industrial areas.

Another pollutant carbon monoxide (CO) is a result of incomplete combustion. It is highly flammable and a silent killer because it is colorless, tasteless, and odorless. Carbon monoxide deprives the body of oxygen because it has an affinity for blood hemoglobin over 200 times that of oxygen.

Student Activity

1. Have your students place cotton balls in various rooms of their homes. Also have them place cotton balls in various locations in a town, village, etc. They should label and record the location of each cotton ball. Tell them to collect the cotton balls after a two week period. Provide the students with magnifying glasses, microscopes, etc. so they can closely analyze and characterize the contents of their cotton balls. Have the students prepare charts displaying locations and cotton ball contents. The students should be able to draw conclusions from the data. (ex. The cleanest room in the house or the cleanest section of a village).

Acid Rain

Acid rain includes forms of rain and snow that are acidic. It causes environmental damage to vegetation, marine life, and to buildings and sculptures exposed to the weather (5). Keep in mind that most rain is somewhat acidic. This is because falling raindrops absorb atmospheric carbon dioxide to form carbonic acid. Therefore any form of precipitation having a pH of 5.6 or less is considered acid rain.

(7) H_2O + CO_2 ----------> H_2CO_3

raindrop carbon dioxide carbonic acid

Acid rain is destructive to fish and other fresh water life. It kills certain species of trees (especially spruce trees) and washes away soil nutrients needed by trees and plant life. It also corrodes metal and cement structures. Limestone and marble (in buildings and statues) turn to a crumbling substance called gypsum upon contact with sulfuric acid. Acid rain primarily refers to sulfuric acid and nitric acid which form as secondary air pollutants. Secondary air pollutants form by further reaction of primary air pollutants. Sulfur trioxide (equation 2) dissolves in water droplets of the atmosphere to produce sulfuric acid, a major component of acid rain.

(8) SO_3 + H_2O ----------> H_2SO_4

sulfur trioxide water sulfuric acid

In addition further reaction of nitrogen dioxide (equation 4) with atmospheric oxygen and water can produce nitric acid (HNO_3), another component of acid rain.

Sulfuric acid in lakes affects fish. It directly interferes with the fish's ability to take in oxygen, salt, and nutrients needed to stay alive. Acid causes mucus to form in fish gills, hampering a fish's ability to absorb oxygen. A low pH will throw off the balance of salts in the fish tissue. Calcium is important for reproduction. Decreased levels of calcium result in weak spines and deformities. (A possible solution for acidic lakes is to neutralize them by adding lime). An indirect effect of sulfuric acid is that it releases heavy metals present in soils. Released aluminum in lakes is lethal to fish. Aluminum burns the gills of fish and accumulates in their organs.

Student Activity

1. Give the students an opportunity to observe what acid rain can do to plant life. Provide the classroom with two identical plants (of the same type, planted in the same type of soil, given the same amount of sunlight, and watered the same amount and at the same time). The only difference (variable) is that one plant is to be watered with water and the other one is to be watered with vinegar. Have the class make daily observations of the plants for a two week period. Tell them to record all information in their science notebooks. Discuss the activity results in class.

2. Have each student collect water / snow samples at home and at various locations throughout his/her community. They should label each sample and note the appearance of vegetation, fresh water life, buildings, etc. at each collecting site. (This information should be recorded). Ask the students to test and record each sample's pH. Discuss and compare the results of this activity in class. Display all the information on charts or on student

made maps of the area.

Conclusion

It is known that using combustion as a source of energy threatens our environment, especially in terms of air pollution and global warming caused by the greenhouse effect. Today syngas is being used to improve the situation. Methanol is made from synthesis gas (syngas), which is the gas that forms when steam reacts with carbon (in the form of coke or coal) or hydrocarbons like natural gas or oil. Syngas opens a cleaner age for coal and oil residues. Turning these residues into syngas allows them to be burned to generate electrical energy without the emission of sulfur dioxide and other polluting gases (6).

What else can be done to lower the risks of combustion? One effort to slow down the greenhouse gas build-up is being carried out by the Monterey Bay Aquarium Research Institute (7). They are performing experiments on disposing of carbon dioxide in the deep ocean. We as a society can employ energy conservation to decrease the overall demand for energy. (ex. Turn off lights and appliances when not in use. Lower thermostats, insulate homes, and car pool and walk whenever possible). Also less trees should be removed from the Earth's surface and numerous trees should be planted to replace the lost ones. We should rely less on wood and fossil fuels for energy and more on other sources such as solar and wind energy. Energy sources should be developed that do not produce carbon dioxide. In addition, a setup could be produced to cool the Earth. (Maybe particles and reflecting mirrors could be placed in the sky and/or a satellite between the Earth and the sun to block out about 2% of the sun's rays).

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Signature: Dana M. Barry Ph.D.

Printed Name/Position/Title: Dana M. Barry, Prof. & Technical Writer

Organization/Address: Work at Clarkson University (Formerly Alfred University)
46 Farmer St. in Canton, N.Y. 13617

Telephone: 315-386-4732

FAX: 315-268-7615

E-Mail Address: dmbarry@clarkson.edu

Date: July 16, 2001

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